THE POISON GLANDS OF THE LARVA OF THE BROWN-TAIL MOTH

(EUPROCTIS CHRYSORRHOEA LINN.)

CORNELIA F. KEPHART

It is well known that certain lepidopterous larvae possess urticating hairs which are the cause of a more or less severe and painful irritation when they come in contact with the human skin. In this country, the one which has attracted the most general attention on this account is the larva of the imported brown-tail moth, *Euproctis chrysorrhoea.* A great many cases of poisoning have been attributed to this species, and one death has been reported as the result of severe internal poisoning caused by inhaling the hairs.

There has been much discussion among scientists as to whether the effect of these hairs is purely mechanical or whether they are actually poisonous, but on the other hand, singularly little definite study has been made of the morphology of the hairs and their underlying structures. It was for this reason that the subject of this paper was suggested by Dr. W. A. Riley and to him the writer is greatly indebted for much kindly criticism and many helpful suggestions.

In 1894 Packard described the poisonous spines of *Lagoa crispata,* stating that the spines themselves were secreted by certain large trichogen cells lying under the rest of the hypodermis and connected with the spines through pore canals in the cuticle. In addition to these cells there were other smaller ones lying in different places above and below the hypodermis, and even in the pore canal itself, which he called "poison nuclei," and which he claims secrete the poison. Ingenitsky (1897) studied several different forms, especially *Ochneria monacha* Linn., and he clearly demonstrated that there are two cells connected with each hair and that the smaller of the two is the trichogen cell, which, after secreting the hair, decreases in size, and that the large cell is the actively secreting poison gland. Aside from the fact that Ingenitsky carefully traced the development of the two cells through all stages of the larva, this view would seem to be the reasonable one, because one would naturally expect to find that the actively secreting cell was larger than one that had already stopped its action. This latter is the same view as that expressed by Holmgren (1895). He also found that the poison hairs were connected with two cells, one somewhat larger than the other, one of which secreted the hair and the other the poison.

In all the forms studied by the different authors, however, the hairs were one of two general types. The first is a simple hair tapering from the base to the tip and containing a poisonous substance, the exact nature of which is not known. When one of these hairs comes in contact with the skin the point breaks off and the contents are liberated in the blood.

The second type is practically the same except that the tip of the hair is in the form of a more heavily chitinized cone which is fitted, cap-like, on the end of the hair and which is readily detachable. In this instance the hair remains on the larva, the tip only breaking off and entering the skin. This type occurs most frequently on the so-called slug caterpillars. These hairs are also said to contain poison, although there has been no evidence brought forward so far to prove that their action is anything more than that of a mechanical irritant.

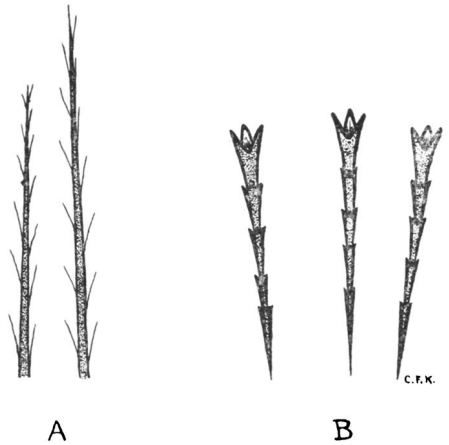

Fig. 1.—Hairs of a larva of *Euproctis chrysorrhoea*. *A*. Ordinary hairs. X 13. *B*. Poison hairs. X 300.

The poison hairs of the brown-tail caterpillar are of a very different type (Fig. 1, B). They are pointed at the base, gradually enlarge toward the tip and have three rows of barbs extending their entire length. They are heavily chitinized, and are filled with a granular substance similar in appearance to the contents of the underlying hypodermal cells. These hairs are found only on the subdorsal and lateral tubercles (Fig. 2, *sdt* and *lt*), arising in bunches of from three to twelve on minute papillae with which the tubercles are thickly covered (Fig. 3, *pap*). Tyzzer (1907) claims to have found as many as twenty on a single papilla, but the writer has not found more than twelve, five to seven being the usual number. They are 70 microns to 100 microns in length and 4 microns to 5 microns in thickness at the larger extremity.

There has been considerable doubt in the minds of many entomologists as to whether the hairs were really poisonous or whether they acted merely as mechanical irritants, but the experiments of Dr. E. E. Tyzzer seem to indicate that there is some specific poison in the hairs.

He found that if one of the nettling hairs be introduced into a drop of blood a peculiar change takes place in the red blood-corpuscles. To quote from his report: "They at once become coarsely crenated, and the rouleaux are broken down in the vicinity of the hair. The corpuscles decrease in size, the coarse crenations are transformed into slender spines which rapidly disappear, leaving the corpuscles in the form of spheres, the light refraction of which contrasts them strongly with the normal corpuscles. The reaction always begins at the basal sharp point of the hair. Minute particles of glass wool, the barbed

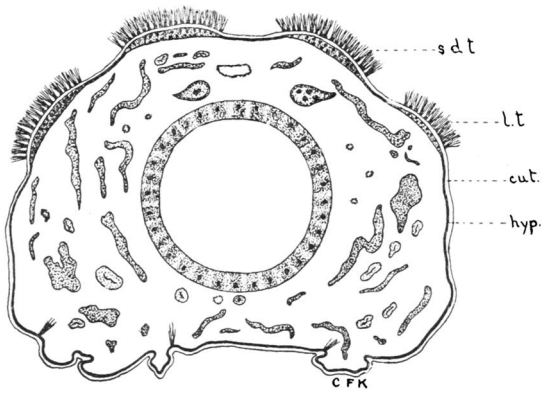

Fig. 2.—Cross section of a larva of *Euproctis chrysorrhoea* showing distribution of poison hairs; *sdt,* sub-dorsal tubercle; *lt,* lateral tubercle; *cut,* cuticle; *hyp,* hypodermis.

hairs of a tussock moth, and the other coarser hairs of the brown-tail, all failed to produce any effect on the red blood-corpuscles." These experiments I have repeated with the same results.

Dr. Tyzzer then tried the effect of heating on the activity of the hairs and found that after baking them for an hour at 110 C. they still gave a typical reaction with the red blood-corpuscles and produced the typical dermatitis when rubbed on the skin. But he found that after baking for an hour at 115 C. they failed to react on the corpuscles, and when rubbed on the skin produced only a slight redness and irritation, such as is caused by any foreign body penetrating the epidermis. All these facts seem to show that there is a definite poisonous substance either in or on the hairs.

He next tried a number of reagents to determine the solubility of the irritating substance. He found that acetone, alcohol, chloroform

and ether had no effect on the reaction of the hairs, whether they were boiled in it or left for days at room temperature. I have found, however, that the hairs from caterpillars that had been kept for five weeks in 70 per cent. alcohol failed to have any effect on the red blood-corpuscles, while those from the cast skins of larvae which had been kept in a dry place for several months produced the characteristic reaction when introduced into a drop of blood. "The nettling hairs remain active after being boiled in pyridin, which boils at a temperature between 106 and 108 C. They also remained active when kept for several days in glacial acetic acid, in 0.5 per cent. acetic and in both 1 per cent. and 0.1 per cent. HCl." But when they were left over night in 1 per cent. and 0.1 per cent. solutions of KOH and NaOH they failed to react either on the skin or on the red blood-corpuscles.

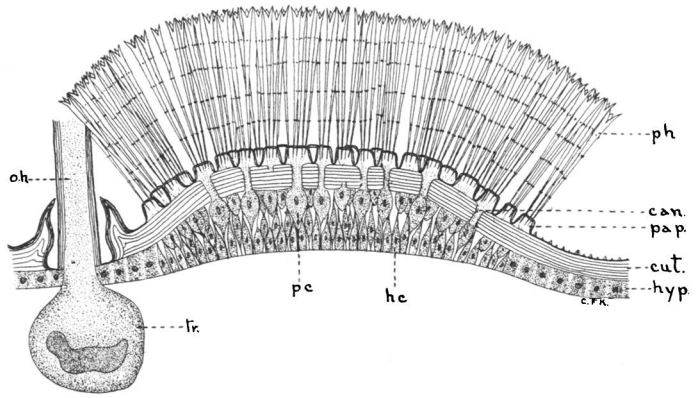

Fig. 3.—Enlarged section of a tubercle; *oh,* ordinary branched hair; *tr,* trichogen cell; *ph,* poison hair, *can,* pore canal; *pap,* papilla; *pc,* poison-secreting cell; *hc,* hair formative cell; *cut,* cuticle; *hyp,* hypodermis. Studied under low power, arrangement of cells semidiagrammatic.

This difference in the action of the weak acids and the weak alkalies is not surprising, since the blood fluid is itself alkaline and the poison is soluble in it.

The next question which arises is whether the poisonous substance is contained in the hair or is merely smeared on the outside, as a number of writers suggest.

If it is on the inside there must be a pore, or opening, of some kind in the point of the hair, because, as has already been stated, the reaction of the red blood-corpuscles always begins around the basal point of the hair and gradually spreads from there, except in the instances where the hair has been broken, when the action takes place rapidly around the point of fracture. In the poison hairs of certain other forms, a tiny opening in the point of the hair is distinctly visible,

but it has been impossible so far to detect any such pore in the poison hairs of the brown-tail caterpillar even with an oil emersion lens.

If the substance is merely smeared on the outside, however, what is its source and how does it reach the hair? If, as some writers suggest, it is secreted in the two red tubercles on the caudal end of the body, then the long hairs as well as the short ones would be covered with it. This has not proved to be the case. Furthermore, Dr. Tyzzer found that if a hair be dried and then placed in some such stain as Loeffler's alkaline methylene-blue solution, the dye first penetrated the point of the hair and then gradually diffused throughout its entire length. These observations strongly indicate that there is a pore in the point of the hair, but there is one thing that Dr. Tyzzer seems to

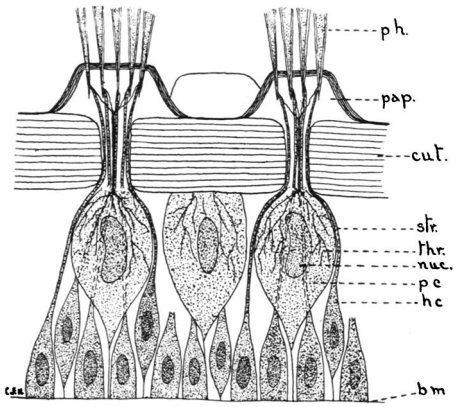

Fig. 4.—Diagram of arrangement of hairs and cells; *ph,* poison hair; *pap,* papilla; *cut,* cuticle; *str,* prolongation of hair formative cell; *thr,* threads of poison; *pc,* poison-secreting cell; *nuc,* nucleus of poison secreting cell; *hc,* hair formative cell; *bm,* basement membrane.

have overlooked. As he says, the nettling hairs occur in groups inserted point first in protuberant rounded sockets or papillae on the subdorsal and lateral tubercles. These papillae are set very close together, although not actually in contact with each other.

Now the hairs of insects are formed simply by the outpushings of certain hypodermal cells, which, projecting above the general level, secrete their cuticle in the form of hair-like prolongations of chitin. The projecting hairs would therefore be hollow and their contents connected directly with the contents of the underlying cell. Then, since the hairs under consideration are inserted point first, this connection must be through the point, and this would leave a pore, or opening, through which the poison may diffuse into the blood when the hair is detached.

The hypodermis of the subdorsal and lateral tubercles is very different in appearance from that of the other regions of the body, being much thicker. This increase in thickness is due to the great length of the cells which lie directly beneath the poison hairs. They are all much elongated, three or four times the length of the ordinary hypodermal cells, and are closely crowded together. The connection between the cells and the poison hairs is effected through pore canals in the cuticle the same as with the ordinary hairs, the only difference being that instead of there being a pore canal for each hair there is one for each papilla on the tubercle, all the hairs on a papilla being reached through the same pore canal (Figs. 3 and 4).

The cells are divided into two groups, one composed of large cells 3.3 microns in diameter, the other composed of smaller ones 1.95 microns to 2.02 microns in diameter. The cells of the first group lie directly under the cuticle (Fig. 3, *pc*) and have crowded out the smaller cells toward the basement membrane, which gives a two-rowed appearance to the hypodermis. These large cells, one of which lies directly under each of the hair-bearing papillae, are composed of granular cytoplasm, corresponding in appearance with that of the ordinary hypodermal cells, with large nuclei which, however, are smaller in proportion to the size of the cell than those of the other group (Fig. 4, *nuc*). In the cytoplasm there are fine threads of a darkly staining substance which converge toward the apex of the cell and unite into a coarser thread which passes through the pore canal in the cuticle and enters the papilla. There it divides again, one thread going to each of the hairs on the papilla (Fig. 4, *ph*).

At first sight these cells bear a slight resemblance to nerve cells with nerve fibers running out from them; but they are rather the poison-secreting cells and the threads, coagulated secretion connected with the individual hairs. This would seem to be the case for three reasons: In the first place, there are no other cells remotely resembling these in any part of the body; this fact in itself being enough to preclude the possibility of their being nerve cells. In the second place, suppose that they were really nerve cells and the hairs instead of being poisonous were merely sensory. What would be the object of having sense organs so loosely attached to the body of the insect that the slightest touch suffices to dislodge them? And what could be their use? Obviously, they could not be tactile, because they are so very short that practically nothing could get to them through the long hairs with which the body is thickly covered. It would take something more stable to serve the purposes of hearing and as for the chemical senses, taste and smell, they are so absolutely different from any other organs of that nature that such a supposition would be unlikely on the face

of it. If sensory, they would seem to be of some sense with which we are unfamiliar and one peculiar to this particular species of caterpillar, especially fitting it for its mode of life. Since its habits are not markedly different from those of a great many of our social caterpillars, the writer is at a loss to account for the necessity of such a highly specialized sense.

Then, since they are evidently not nerve cells, and since they are actively secreting, it would seem legitimate to assume that they are poison cells. The hairs themselves are formed by the smaller cells, as will be shown later, the papillae are merely cuticular appendages and there is nothing else present for which active gland cells could possibly be used.

The cells composing the second group are of a very different appearance from those just described. They are much smaller; measuring from 1.95 microns to 2.02 microns in diameter. They are fusiform in shape, irregularly arranged, and appear as though crowded out of their regular position by those around them. There is comparatively little cytoplasm and it does not contain the threads of poisonous substance (Figs. 3 and 4, *hc*). These cells correspond in number with the hairs and each cell is connected by means of a strand of cytoplasm with a hair. The strands of cytoplasm are in fact nothing more nor less than portions of the cells which extend up around and between the poison cells (Fig. 4, *str*), through the pore canal and papilla directly to the hairs. In other words, the smaller cells are the hair formative cells for this particular kind of a hair.

The basement membrane extends along beneath the second group of cells and is very easily detected, much more so in fact than in the other parts of the body wall; and all the cells, whether poison-secreting or hair formative, are connected with it either lying directly on it or connected by means of fine threads of the cell substance.

Beille (1896) described something very similar to this as obtaining in one of the processionary caterpillars, *Cnethocampa pityocampa* Borowski. In that species the surfaces of the tubercles bearing the urticating hairs are divided into four areas by two bands which cross the tubercle at right angles to each other and which are free from hairs. The four sectors thus made are covered with chitinous papillae which bear the poison hairs and which are connected with the subjacent parts by pore canals in the cuticle in the same way as those of the brown-tail. "The glandular part exists only under the sectors covered with hairs. These glands are separated from each other by connective-tissue strands and a membrane of the same nature separates them from the subjacent organs. These glands are unicellular and are in the form of very elongate pears. . . . In the narrower parts one sees a canal

which is continuous with each of those which cross the chitinous area. These glands are therefore analogous in their structure to those which correspond to the large hairs, and ought to be considered as hypodermal glands."

Unfortunately, there are no illustrations in his paper, and it is somewhat difficult to interpret his descriptions. He says nothing to prove the glandular nature of these cells, and the probability is that some of those that he describes are the hair-formative cells. Judging from the brown-tail, his connective tissue strands are the prolonged distal portions of the hair formative cells. However, that a condition exists similar to that found in the brown-tail seems probable and it is quite probable that further work done on the larvae of the processionary caterpillars will bring out still further evidences of the similarity of their structures.

Probably the nearest approach to the structures found in the brown-tail are those recently described by Eltringham (1914) as occurring in the closely related species *Porthesia* (*Euproctis*) *similis* Fuess. He says that these hairs are connected with *two* rows of hypodermal cells similar to the one row in Figure 3, which cells, he thinks, doubtless secrete the hairs. If two rows of hypodermal cells do exist in this form it is an aberrant condition, and from Eltringham's description and figures it seems probable that what he took for a second row of cells was either an invagination of the body wall, a portion of the hypodermis from some other part of the body which had become displaced in the process of sectioning, or else some other tissue entirely.

There are also figured some very peculiar looking structures which he calls the "plume-like structures." These are said to occur among the urticating hairs and to "arise from a chitinous socket, differing little, if at all, from the sockets of the larger branched hairs, and having at its base several cells apparently of a glandular nature." These "plume-like structures" correspond in position to some of the large branched hairs of the brown-tail and it is possible that what Eltringham took for a single structure is really a group of branched hairs, each hair being connected with one of the cells at the base of the structures.

More work will have to be done on all the poisonous forms before generalizations can be made, but, taking all things into consideration, it is clear that the short barbed hairs occurring on the subdorsal and lateral tubercles of *Euproctis chrysorrhoea* contain a definite poisonous substance and do not act merely as mechanical irritants; and it is probable that a similar condition of affairs exists in a number of different species.

SUMMARY

1. Tyzzer's statement that a definite poisonous principle is contained in the short barbed hairs of the larva of the Brown-tail Moth is confirmed.

2. This substance is secreted by certain specialized hypodermal cells and is liberated in the blood through the sharp basal point of the hairs when they come in contact with the human skin.

3. The poison glands are larger and fewer in number than the cells which form the hairs, there being one poison cell for each papilla on the tubercle instead of one for each hair.

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